# 13 IMPLICATIONS FOR MANAGEMENT AND POLICY

The goal of the Maryland Biological Stream Survey (MBSS or Survey) is to provide natural resource managers, policymakers, and the public with the information they need to make effective natural resource decisions. For this reason, the Survey was designed to answer a set of 64 management questions. These questions (see Appendix A) represented the direction and range of natural resource management concerns in 1995. The results described in this MBSS report provide scientifically defensible and management-relevant answers to the majority of these questions, in some cases the first such answers ever obtained. At the same time, certain management concerns have changed and programmatic needs have evolved. Some of the 64 questions are less important, while new questions need to be answered. The discussion in this chapter summarizes the answers to original MBSS questions and to other questions of concern. The next section describes the relevance of these answers to current natural resource management and policy initiatives. Finally, questions that remain to be answered and their implications for future implementation of the Survey are discussed in Chapter 14-Future Directions of the MBSS.

## 13.1 ANSWERS TO MBSS MANAGEMENT QUESTIONS

At the early stages of the Survey, environmental and natural resource managers developed a list of management questions that potentially could be answered with MBSS data. The Survey was designed specifically to answer many of these questions at a statewide and basinwide level and thus to provide a greater understanding of the condition of Maryland's non-tidal streams and the stressors affecting stream resources. Over the course of the 1995-1997 MBSS, we addressed many of these questions through careful analysis of the data. Detailed answers are incorporated throughout this report. Here, we summarize answers to MBSS questions, which fall under the general topics of physical characteristics, water chemistry, biological resources, landscape characteristics, resource-stressor associations, and resource-landscape associations. Because management concerns and priorities evolve, we have also addressed several new questions of interest to DNR, that have been identified over the course of the Survey.

For brevity, questions are answered below with a short summary of statewide results. Additional information may be found in the referenced sections of this report. Basin-specific answers to many of the questions are also found in the sections noted. In addition, basic water chemistry, physical habitat, and fish population estimates have been reported in individual basin data summaries for each sample year: 1995 (Roth et al. 1997, Appendix F), 1996 (Roth et al. 1998, Appendix D) and 1997 (Roth et al. 1999).

### 13.1.1 Physical Characteristics

How many wadeable stream miles of each stream order are in the study area?

- According to the 1:250,000 base map used by the Survey, there are 5,820 miles of first- order, 1,499 miles of second-order, and 692 miles of third-order streams, for a total of 8,010 miles of first- through third-order streams in the study area (Appendix B). This represents the vast majority of stream miles in Maryland.

What is the geographic distribution of these streams?

- The greatest number of first- through third-order stream miles were in the Middle Potomac basin. The breakdown of stream miles by order for all 17 basins sampled in the Survey is shown in Appendix B.

How many stream miles in the study area are remote?

- An estimated 17% of stream miles were difficult to access (i.e., received the highest remoteness rating) and another 26% were moderately difficult to access (Section 7.2.5 and Appendix D).

What % of streams in the study area are estimated to be ephemeral (i.e., dry at the time of summer sampling)?

- Less than 5% of stream miles were ephemeral. The percentage varied slightly by year. In 1996, a wet year, an estimated 2.8% of stream miles in sampled basins were ephemeral, compared with 5.3% in 1995 and 4.2% in 1997 (Section 10.1).

What % of stream miles are obstructed by beaver dams or other barriers?

- An estimated 4% of stream miles had evidence of beaver activity. Artificial blockages were observed at 18 sites out of the 905 sampled during summer (Section 7.2.2 and Appendix D).

What % of stream miles are channelized with bank revetment or artificial banks?

- Statewide, an estimated 17% of stream miles were channelized. Individual basins had up to 81% of stream miles channelized (Section 7.2.2).

What % of stream miles have low bank stability?

- An estimated 13% of stream miles received ratings of poor for bank stability, while another 34% were rated as marginally stable (Appendix D).

  Assessments of bank erosion potential showed similar results. Statewide, 7% of stream miles had highest potential for bank erosion, while another 35% had high potential, according to an erodibility index that combines several aspects of bank condition (Section 7.2.3).

What % of stream miles have selected types of riparian buffers?

- Fifty-eight percent of stream miles had forested buffers, 14% had other kinds of vegetated buffers (wetland, old field, tall grass, or lawn), and 28% had no effective vegetation in the riparian zone. (Section 7.2.1 and Appendix D).

What % of stream miles have selected widths of riparian buffers?

- Statewide, 40% of stream miles had at least a 50-m riparian buffer, 13% had a 19-49 m buffer, 12% had a 6-18 m buffer, 7% had a 1-5 m buffer, and 28% had no effective buffer. Riparian buffer widths varied by basin (Section 7.2.1 and Appendix D).

What % of stream miles have little shading?

- Statewide, 8% of stream miles had very little shading (0-25% coverage), and 10% had little shading (25-50% coverage) (Appendix D).

What % of stream miles have high aesthetic quality?

- An estimated 43% of stream miles had high aesthetic quality (Section 7.2.5 and Appendix D).

What % of stream miles have low instream habitat quality (e.g., high embeddedness)?

- A number of parameters were used to evaluate different aspects of instream habitat quality (Section 7.2.5 and Appendix D). Twelve percent of stream miles had poor instream habitat structure and 31% had poor epifaunal substrate. Velocity/depth diversity was rated poor in 12% of stream miles, while 10% rated poor for pool/glide/eddy quality. Riffle/run quality was poor in 16% of stream miles and 28% of stream miles had a high percentage of embeddedness.

What % of stream miles in the study area are estimated to be publicly vs. privately owned?

- Statewide, an estimated 79% of stream miles were on private land, while only 17% were public. Within some individual basins, the extent of private ownership was even higher (Section 13.2.5).

What is the geographic distribution of streams with these physical characteristics across the state?

- Geographic variation was noted for many of the physical habitat characteristics recorded by the Survey. Comparisons among basins are presented for several individual parameters (Section 7.2).

What % of stream miles have habitat conditions that differ from reference conditions as measured by indicators of stability (e.g., bank erosion) and diversity (e.g., substrate types)?

- The Physical Habitat Index (PHI), which combines multiple aspects of physical habitat condition, rated 29% of stream miles as poor and 22% as very poor habitat, in comparison with reference conditions (Section 7.3).

What is the relationship between the degree of aesthetic quality and remoteness?

- There is a positive correlation between aesthetic quality and remoteness ($r^2$=0.28) (Section 7.2.5).

### 13.1.2 Water Chemistry

What % of stream miles in the study area have low pH or acid neutralizing capacity (ANC)?

- An estimated 2.6% of stream miles had spring pH less than 5, while another 6.4% had spring pH 5-6. Summer results were similar: 1.8% of stream miles had summer pH less than 5, while 4.2% had summer pH 5-6. An estimated 28% of stream miles were in low ANC classes, including 2% chronically acidic (ANC < 0 $\mu$eq/l), 4% highly sensitive to acidification ($0 \leq$ ANC < 50 $\mu$eq/l), and 22% sensitive to acidification ($50 \leq$ ANC < 200 $\mu$eq/l). Results varied by basin and stream order, with first-order streams having a greater percentage of stream miles with low pH and ANC (Section 6.2 and Appendix E).

What % of stream miles have high dissolved organic carbon (DOC), sulfate ($SO_4$), or nitrate-nitrogen ($NO_3$-N)?

- Statewide, 59% of stream miles had $NO_3$-N concentrations greater than 1 mg/l, a level indicative of anthropogenic influence. Twenty-nine percent of stream miles had greater than 3 mg/l, and 5% of stream miles had greater than 7 mg/l $NO_3$-N (Section 8.2 and Appendix E). An estimated 6% of stream miles had DOC greater than 10 mg/l, and 2% of stream miles had $SO_4$ concentrations greater than 50 mg/l (Appendix E).

What % of stream miles have dissolved oxygen (DO) less than the state water quality standard?

- Statewide, 3% of stream miles had DO concentrations less than 3 ppm. An additional 3% had 3-5 ppm DO (Section 8.2 and Appendix E), falling below the state surface water quality standard of 5 ppm.

What are the geographic distributions of streams with these water chemistry characteristics across the state?

- Low pH and ANC conditions were most common in the Appalachian Plateau and Southern Coastal Plain (Sections 6.2 and 6.4). High $NO_3$-N was most common in central Maryland and the Eastern Shore (Section 8.2).

What are the average concentrations of these water chemistry parameters across the state?

- The mean statewide $NO_3$-N concentration was 2.45 mg/l (Section 8.2). Mean $NO_3$-N was higher, about 4.0 mg/l, among streams in predominantly agricultural watersheds (Section 9.3).

How has the number of acidic and acid-sensitive streams (based on ANC) changed statewide since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS)?

- The percentage of acidic and acid-sensitive stream miles was lower in the 1995-97 MBSS (26% of stream miles had ANC < 200 $\mu$eq/l), compared with the 1987 MSSCS (33%). The percentage of acidic stream miles was also lower in the 1995-97 MBSS (1.4% of stream miles had ANC < 0 $\mu$eq/l) than in the 1987 MSSCS (3.6%) (Section 6.4).

### 13.1.3 Biological Resources

What % of stream miles in the study area have no fish, non-gamefish, and gamefish species?

- Statewide, an estimated 11% of stream miles had no fish. When very small headwater streams were excluded from this estimate, 4% of stream miles statewide had no fish (Section 4.1.1).

What % of stream miles have exotic species?

- Forty-six percent of stream miles contained non-native fish species. (Section 12.5)

What % of stream miles have rare species?

- Although stream mile percentages were not calculated, the Survey captured six fish, one amphibian, and five mussel species listed by the Maryland Natural Heritage Program as rare. Additional analysis of MBSS data identified nine other fish species that may be considered rare because of their limited occurrence among the sites sampled. Locations of state-listed and other rare fish species were mapped to identify potential areas of conservation importance (Section 12.2).

What is the geographic distribution of fish species across the state?

- Of the 85 fish species collected, three (largemouth bass, bluegill, and pumpkinseed) were found in all basins. On the other end of the spectrum, six basins contained one or two fish species (including johnny darter, striped shiner, flier, shorthead redhorse, stripeback darter, banded darter, Atlantic menhaden, and longnose gar) unique to that basin. Therefore, most fish species were found in more than one, but not all, river basins in Maryland. When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—was considered, 51 species occurred in all three regions and less than 10 were unique to any one region (Section 4.1.1 and 12.1.1).

What is the average density (number per stream mile) of individual fish species in the study area?

- The most abundant fishes were blacknose dace, with an average density of 1,970 individuals per stream mile, and mottled sculpin, estimated at 1,370 per stream mile. The most common gamefish species were brook trout (54 per stream mile) and largemouth bass (53 per stream mile). Statewide estimates of density (number per stream mile) and abundance (total number in the study area) for all individual fish species are given in Appendix E (Section 4.1.1 and Appendix E).

Which basins support the highest quality fisheries (i.e., have the greatest number of gamefish above minimum size in first- to third-order streams)?

- The abundance of harvestable-size gamefish was greatest in the Gunpowder basin, with an estimated 23,565 harvestable-size gamefish in first- to third-order streams (Section 4.1.2 and Appendix E).

What % of stream miles in the study area have fish with abnormalities (pathologies and parasites)?

- Forty-four percent of stream miles had fish with pathological anomalies. Two percent of stream miles had gamefish with pathological anomalies (Section 4.1.3).

What % of stream miles have fish with selected types of abnormalities?

- Forty percent of stream miles had fish with skin anomalies, 7% had fish with skeletal anomalies, and 9% had fish with ocular anomalies (Section 4.1.3).

What % of stream miles have selected types of herpetofauna (e.g., frogs and toads, salamanders, and reptiles)?

- Amphibian species (frogs, toads, and salamanders) were the most commonly observed groups, with frogs and toads present at an estimated 44% of stream miles and salamanders present at an estimated 40% of stream miles. Reptiles were less frequently observed: turtles were present at an estimated 7% of stream miles, snakes at 5%, and lizards at 0.4% (Section 4.3).

What is the geographic distribution of reptiles and amphibians across the state?

- In general, the statewide pattern of total amphibian and reptile species richness declines from the western to eastern parts of the State. Only two amphibian (green frog and bullfrog) and one reptile (northern water snake) species were present in all 17 basins. At the other extreme, six basins contained one or two amphibian or reptile species (including Jefferson salamander, northern fence lizard, gray treefrog, redbelly turtle, eastern smooth earth snake, rough green snake, and smooth green snake) unique to that basin. Therefore, most of the 45 amphibian and reptile species collected were found in more than one, but not all, river basins in Maryland. When the distribution of amphibian and reptile species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 18 occur in all three regions, with the number of species unique to any one region ranging from two in the Coastal Plain to six in the Highlands. Salamander species richness showed the most striking geographic variation, with highest species richness in the westernmost basins (Sections 4.3 and 12.1.3).

Where are additional populations of rare fish and herpetofauna not previously documented located?

- Locations of state-listed and other rare fish species were mapped to identify potential areas of conservation importance (Section 12.2). One rare amphibian species (Jefferson salamander) was found at 1 site in the North Branch Potomac basin (Sections 12.1.3 and 12.2).

To what degree do the flowing, non-tidal waters of the state have balanced indigenous populations of biota as measured by the fish community (e.g., What is the % of stream miles in degraded condition based on the Index of Biotic Integrity (IBI))?

- Statewide estimates based on the fish IBI indicate that 20% of stream miles were in good condition, 25% fair, 15% poor, and 14% very poor condition. A total of 74% of stream miles (all but the smallest headwater streams, where few fish are expected) were rated using the fish IBI (Section 5.3.1).

To what degree do the flowing, nontidal waters of the state have balanced indigenous populations of biota as measured by the benthic macroinvertebrate community (e.g., What is the % of stream miles in degraded condition based on EPT taxa, Hilsenhoff Biotic Index, or Benthic Index of Biotic Integrity)?

- Statewide estimates based on the benthic IBI indicate that 11% of stream miles were in good condition, 38% fair, 26% poor, and 25% very poor condition (Section

5.3.2). Assessments based on the Hilsenhoff Biotic Index showed that 33% of stream miles were in good condition, 37% fair, 14% poor, and 2% very poor condition (Section 5.3.3).

### 13.1.4 Landscape Characteristics

What % of area (acres) in the study area is in the following land use categories: agriculture, forest, urban, and wetlands?

- To quantify land uses that may affect streams sampled, the Survey characterized land uses within the watersheds upstream of each site. Statewide, the dominant land use in these site-specific catchments was forest (with a mean percent cover of 46%), followed by agriculture (44%) and urban (9%). On average, wetlands made up only a small fraction of catchment areas (Section 9.2).

What is the geographic distribution of these land use categories in the study area?

- The diversity of land uses in Maryland can be seen in a statewide map (Section 3.5). Within individual basins, agricultural land use was greatest at sites in the Susquehanna basin (with a per-site mean of 66%) and in the Middle Potomac, Gunpowder, and Elk basins (all 63%). Sites in the North Branch Potomac had a mean of just 15% agriculture, while the mean in the remaining basins ranged from 22 to 60% agricultural land. Forest cover was most extensive for sites in the North Branch Potomac basin (83%) and least extensive in the Patapsco basin (1996 sampling, 21%). As expected, urban land use was greatest in the Patapsco (31%) and Potomac Washington Metro (23%) basins. Four basins–Patuxent, West Chesapeake, Patapsco (1995 sampling), and Bush–had a mean percentage of urban land use between 10 and 20%. The remaining basins had a mean percentage of urban land use less than 10%. In all basins, wetlands accounted for less than 5% of catchment land area (Section 9.2).

Where are the minimally affected streams and what are their land use/landscape characteristics?

- Minimally-affected streams (those receiving good to fair ratings by the fish and benthic IBIs) were located throughout the state (Section 5.3). Further analysis of sites rated as good by the fish IBI showed that these streams were generally characterized by less urban development. Sites rated as good by the fish IBI had an average of 4% urban land use, compared with an average of 9% for all sites (Section 9.4.1)

### 13.1.5 Resource-stressor Associations

What % of chronically acidic stream miles in the study area are associated with acid mine drainage (AMD) or acidic deposition as measured by pH, ANC, and $SO_4$?

- Among chronically acidic stream miles (those with ANC < 0 $\mu$eq/l), acid mine drainage was the dominant source of acidification in 38% of stream miles and acidic deposition was dominant in 42%. Organic acids influenced 9% of chronically acidic streams, while another 11% were influences by both organic ions and acidic deposition (Section 6.3).

What is the relationship (subpopulation analysis or correlation) between water chemistry (ANC, pH, DOC, $SO_4$, $NO_3$, and DO) and abundance of fish species?

- Fish species richness and density (number of fish per stream mile) declined at low-ANC sites. Also, fish IBI scores showed a decline with low ANC and low pH, with IBI scores dropping into the poor range at pH 5-6 (Section 6.5). For individual species, dramatic declines were seen in fish species composition and abundance in low ANC classes (Section 6.7).

What is the relationship between stream channelization and the abundance of fish species?

- Fish IBI scores decreased with low scores for channel alteration (Section 7.5).

What is the relationship between riparian buffer and the abundance of fish species?

- Fish IBI scores increased at sites with greater riparian buffer width (Section 7.5).

What is the relationship between remoteness and abundance of fish species?

- Remoteness was strongly related to the abundance of brook trout. Among remote sites, density was estimated at 138 brook trout per stream mile, compared with 36 individuals per stream mile at non-remote sites (Section 7.5).

What % of stream miles in the study area have suitable physical habitat and would be expected to have desired species (e.g., gamefish or endangered species) if water chemistry or other stressors were absent (i.e., are candidates for restoration)?

- Statewide, 20% percent of stream miles were rated as good and 29% fair by the PHI, indicating together that about half of the stream miles in the State are comparable with reference conditions for physical habitat (Section 7.3).

### 13.1.6 Resource-landscape associations

What is the relationship between land use and stream resources using indices of the biological community such as the IBI?

- Statewide, both the fish and benthic IBI decreased with increasing amounts of watershed urbanization, whether measured as all urban land, low-intensity, or high-intensity urban only. Benthic IBI scores increased with the percentage of catchment area in forest cover. The IBIs were less effective in detecting effects of agriculture at the watershed scale. The Hilsenhoff Biotic Index increased (indicating degradation) with both urban and agricultural land use and was negatively correlated (indicating better conditions) with the amount of forest cover. In many cases, by reducing variability, relationships within individual basins provided a clearer picture of land use relationships than did statewide results (Section 9.4).

### 13.1.7 New Questions

What is the quantity of available physical habitat in streams within the study area, in terms of width, depth, discharge, and amount of woody debris?

- Statewide, the mean stream width was 3.4 m and mean thalweg depth (depth at the deepest part of the channel) was 22 cm. Stream discharge, which tends to increase with watershed area, stream width, and depth, had a mean value of 2.7 cubic feet per second (cfs). The mean number of rootwads and other woody debris was 4 pieces per 75-m stream segment. As expected, values for habitat quantity varied by basin and stream order (Section 7.2.6).

How do the geographically diverse MBSS data compare with data from DNR's CORE/Trend monitoring program (a less extensive but long-term sampling effort)?

- In a comparison of nutrient data, the statewide mean nitrate-nitrogen concentration from the MBSS data was 2.45 mg/l, while CORE/Trend samples from the same time period (spring 1995-97) had a mean of 1.82 mg/l. Mean $NO_3$-N concentrations in the Youghiogheny and the North Branch Potomac basins were both consistently low, showing little difference between monitoring programs. However, differences were more apparent in other basins, and Spearman correlation analysis showed that basin $NO_3$-N concentrations were ranked differently by the two monitoring programs. Differences between the two programs may be explained in part by differences in sample site locations and stream size.

How do MBSS results for stream chemistry, physical habitat, and biological communities vary from year to year, and do differences correspond with annual changes in weather conditions?

- Within the three basins resampled by the Survey in two different years (Youghiogheny, Patapsco, and Choptank), the mean value in each sample year for the fish IBI, benthic IBI, PHI, and nitrate-nitrogen concentration were examined. Although some small differences were detected, virtually all were within the range of error (±1 standard error). Statewide, Maryland received an average of 38% more rainfall than normal in 1996, while 1995 and 1997 each received an average of 7% less rainfall than normal. However, the large amount of rain that fell in 1996 did not result in predictably lower (or higher) values for any of the parameters examined (Chapter 10).

Which stressors are most extensive throughout the state?

- The most extensive source of stress was physical habitat degradation, which affected an estimated 52% of stream miles. Riparian vegetation was lacking from 28% of stream miles. Agricultural land uses were influential at 17% of stream miles, while urban land use was a potential stress at 12% of stream miles. Nutrient concentrations were high in 5% of stream miles statewide. Acidic deposition affected an estimated 21% of stream miles, while acid mine drainage affected 3% of stream miles (Section 11.1).

What site-specific information can the Survey provide to detect stream degradation and identify sources of stress at particular locations?

- To screen sites, the fish IBI and benthic IBI were used to identify individual sites with low biotic integrity. Statewide, 203 sites were rated as poor to very poor for both IBIs, and another 336 rated poor to very poor for either the fish or benthic IBI. For each site, site information and physical and chemical parameters indicative of potential stressors were compiled to facilitate further investigation (Section 11.3 and Appendix F).

In addition to species listed by the Maryland Natural Heritage Program, what fish species might be considered at risk, based on low frequency of occurrence in MBSS sampling?

- Survey data were used to identify freshwater fish species occurring at the lowest frequency. In addition to six Heritage-listed fish species, there were nine other fish species that occurred just as infrequently and could also be considered at risk in Maryland streams; rainbow darter, comely shiner, striped shiner, American brook lamprey, checkered sculpin, warmouth, pearl dace, johnny darter, and swamp darter (Section 12.2).

What is the distribution of non-native mussel and fish species?

- Asiatic clams were found in 13 of the 17 river basins sampled, although they were found in relatively few sites in each basin. The zebra mussel was not found during 1995-1997 MBSS sampling. Non-native fish species were found in all basins (Section 12.5).

What % of stream miles in a particular watershed or county have streams in good, fair, or poor condition according to the biological and physical habitat indicators?

- A pilot analysis of biological and physical habitat indicator results for selected watersheds and counties was conducted to demonstrate the utility of MBSS data for calculating estimating condition at these finer scales (Section 13.2.5).

## 13.2 RELEVANCE TO CURRENT MANAGEMENT AND POLICY INITIATIVES

Information from the Survey is already being used to support management and policy initiatives at DNR. Specifically, the answers to the questions presented in the preceding section are helping DNR managers and policymakers to address the primary objectives of the MBSS:

- assess the current status of biological resources in Maryland's non-tidal streams;

- quantify the extent to which acidic deposition has affected or may be affecting biological resources in the state;

- examine which other water chemistry, physical habitat, and land use factors are important in explaining the current status of biological resources in streams;

- compile the first statewide inventory of stream biota;

- establish a benchmark for long-term monitoring of trends in these biological resources; and

- target future local-scale assessments and mitigation measures needed to restore degraded biological resources.

By addressing these objectives, the Survey supports a wide range of current management and policy initiatives at Maryland DNR and other agencies. For example, the Survey provides DNR with (1) a targeting tool that is statewide, (2) a baseline to use when designing future monitoring programs, and (3) data that can be used in an integrated way to assess cumulative impacts. The following sections describe specifically how the principal results of the 1995-1997 MBSS are contributing to current natural resource and environmental programs.

### 13.2.1 Inventory of Maryland's Aquatic Resources

DNR's mandate is to effectively manage the natural resources of the state. It is axiomatic, therefore, that DNR needs to know what these resources are, where they occur, and how abundant they are. Aquatic ecosystems, and streams in particular, are an abundant and diverse resource not easily characterized. With the completion of the 1995-1997 MBSS, DNR has its first comprehensive picture of Maryland's stream resources.

From MBSS data, we know that more than 8,000 miles of streams run through the state and that approximately 60 million fish live in these streams. More importantly, we have improved our knowledge of where individual species, including recreationally important and rare species, exist. We also know the extent and geographic distribution of physical features and water chemistry parameters that describe both natural variation and human influences. Such knowledge is the first step in developing new holistic approaches to assessment and practical strategies for the management of natural resources.

The Monitoring and Non-Tidal Assessment (MANTA) Division of DNR is charged with building the knowledge base on Maryland's stream resources and is using the MBSS (among other programs) to do so. The results of the Survey to date have enabled DNR to plan strategies and set stewardship goals not possible previously. At the same time, the experience of implementing the Survey and the results themselves are being used by MANTA to design future monitoring and assessment programs leading to a statewide water monitoring strategy.

Several other parts of DNR are making use of MBSS data. The Fisheries Service has the critical role of managing fisheries resources and enhancing fishability throughout the state. The Survey's statewide and basinwide estimates for each fish species can be used to supplement Fisheries Service data and better target management efforts. As one example, information on basins that have at-risk populations of brook trout can be used to focus future fisheries management decisions.

While gamefish populations are of interest to DNR and the public, both entities also place substantial value on maintaining and enhancing the state's aquatic biodiversity. The Heritage and Biodiversity Conservation Programs of DNR are charged with identifying and conserving rare species and other components of Maryland biodiversity. The Survey provides statewide, statistically rigorous data on the abundance and distribution of fish (and to a lesser degree other organisms) that can be used to validate and supplement natural heritage program information. Results of the 1995-1997 MBSS confirm the status of species listed as rare by the natural heritage program, while providing evidence for consideration of other species potentially at risk. Information on concentrations, or hotspots, of biodiversity components (rare fish species collected by the Survey are concentrated in five regions of the state) are already being used to support PPRP's Smart Siting initiative and DNR's Unified Watershed Assessment.

The information on the abundance and geographic distribution of stream resources, especially aquatic biota, is valuable for many other groups with mandates for or interests in protecting Maryland's streams. These include the U.S. Fish and Wildlife Service, Biological Resources Division of USGS, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency's Mid-Atlantic Integrated Assessment. Maryland counties and private organizations, such as Save Our Streams, are also using MBSS data.

**13.2.2 Current Condition of Maryland's Streams**

Perhaps the most important information for a natural resource manager is—What is the condition of the resource? This information is critical to answering the questions of (1) where Maryland's stream problems are, (2) what they are, and (3) how can they be fixed.

With the completion of the 1995-1997 MBSS, DNR has its first comprehensive picture of the condition of stream resources. The critical step in describing stream condition was appropriately defining "stream degradation" and developing the indicators needed to measure it. Consistent with current ecosystem-based approaches, the Survey defines degradation as "loss of biological integrity based on deviation from reference condition." Therefore, one of the key accomplishments of the Survey was the development of two reference-based biological indicators—the fish IBI and benthic IBI— that could be used to identify degradation anywhere in the state.

The benthic IBI indicates that approximately one-half of all Maryland streams are in poor or very poor condition. Somewhat fewer streams are poor or very poor according to the fish IBI. The estimated proportion of streams that are degraded statewide, or within a specific river basin, depends on the threshold chosen. The Survey has chosen the low end of reference values (values that capture approximately 10% of reference sites) to signify degradation, although streams marginally above this level are rated as "fair." By effectively quantifying stream condition, these indicators provide a valuable tool for setting protection levels and forming restoration targets.

As a specific example, DNR incorporated mean values by 8-digit Maryland watersheds for both the fish IBI and benthic IBI in the State's Unified Watershed Assessment required under the Clean Water Action Plan. These indicators provided some of the best biologically based information provided to EPA by any state. These IBIs were used with other indicators to help designate both Category 1 (priorities for restoration) and Category 3 (priorities for protection) watersheds within Maryland.

In addition to supporting DNR's management programs, the identification of degraded stream segments has implications for protection under the Clean Water Act. Section 101 of the Act states that physical, chemical, and biological integrity of waters should be maintained. Stream segments that fail to do this can be designated as degraded and not attaining designated uses as part of their water quality standards. The Maryland Department of the Environment

(MDE) implements the water quality standards program and prepares a 303d list of streams not meeting their designated uses. Streams rated as poor or very poor by MBSS data are candidates for listing on the 303d list. Ultimately, total maximum daily loads (TMDLs) must be developed for streams on this list; in the case of MBSS-rated streams, additional monitoring may be needed to verify degradation and determine the specific cause and how it can be controlled.

As MDE moves forward with development of biological criteria to support their water quality standards program, the MBSS biological indicators will likely be a primary focus. Incorporating quantitative, reference-based indicators (such as the MBSS fish IBI and benthic IBI) into criteria is consistent with current EPA guidance.

Assessments of stream condition based on the survey's ecological indicators were also provided to the State's Tributary Strategies program. Estimates were calculated for each of the state's 10 Tributary Strategies basins, which are aggregations of the 17 major river basins used by the survey (Figure 13-1).

### 13.2.3 Trends in the Condition of Maryland's Streams

One of the most frustrating problems facing natural resource and environmental managers is the lack of historical monitoring data against which to compare current monitoring results. Determining the change in a resource over time is often essential to understanding its condition and prospects for future decline or improvement. One of the most important reasons for conducting the 1995-1997 MBSS was to provide a comprehensive, statewide baseline for future monitoring efforts. Now that it is complete, DNR has many options for future monitoring that can address short-term and long-term trends.

Determining trends, or change over time, can answer three important questions: (1) is the resource stable, declining, or improved in comparison to desired conditions? (2) is the resource declining in response to changes in specific stressors? and (3) is the resource improving in response to specific management measures? While the answers to the questions must generally await a second round of monitoring, some trends questions are currently being addressed.

The Survey had the specific goal of determining whether the extent of acid-sensitive streams in Maryland had changed since the 1987 Maryland Synoptic Stream Chemistry Survey (MSSCS). Results indicate that the proportion of streams with less than ANC of 200 μeq/l has dropped slightly from 33% to 26%. This information can be compared with air emissions data from EPA and with acidic deposition data from the National Acid Deposition Program; current results and future trends have important implications for assessing the effectiveness of controls instituted as a result of the 1990 Amendments to the Clean Air Act.

Future trends detection using the MBSS baseline monitoring data will likely prove invaluable for addressing two areas of projected change in Maryland: (1) continued population growth and the land use changes that will accompany associated development and (2) climate change. The Governor's Smart Growth plan is a promising solution to contain sprawl development and degradation of the landscape, but monitoring of trends in resource condition will be needed to determine if it is being implemented effectively. Lastly, the current baseline of stream monitoring data should be incorporated into monitoring the effectiveness of specific restoration projects to be funded under the Clean Water Action Plan and other initiatives.

### 13.2.4 Impacts of Human Activities on Maryland's Streams

While reliable information on the condition of Maryland's streams is critical to effective management, problems cannot be remedied unless we know their causes. For this reason, the Survey did not restrict itself to biological sampling; water chemistry, physical habitat, and other parameters related to possible stressors were included. By collecting all these parameters in conjunction with biological data at each stream site, the Survey can make accurate estimates of the relative contributions of different stressors and begin to investigate the cumulative effects they have across the landscape.

MBSS results indicate that physical habitat degradation is the most pervasive source of stream problems, affecting 52% of stream miles in the state; in descending order of extent of stream miles affected, other important stressors are lack of riparian vegetation (28%), acidic deposition (21%), agriculture (17%), urbanization (12%), nutrients (5%), and acid mine drainage (3%). This confirms that while acid mine drainage effects may be severe on individual streams, acidic deposition affects many more streams. MBSS results also indicate that many streams are affected by a combination of stressors, all of which need to be considered to assess the cumulative impact of human activities.

Foremost among the widespread stressors are physical habitat degradation and the agricultural and urban land uses that contribute to adverse effects. The Physical Habitat Index developed by the Survey (in a manner analogous to the IBIs) provides a means of differentiating natural variation from human influence on this critical parameter. Analysis of the MBSS results has identified important associations between many stressors and the fish and benthic IBIs. For example, fish and benthic IBIs decline steadily with increasing amount of urban land; while at the same time these IBIs increase with increasing habitat quality (as determined by the Physical Habitat Index). The use of these rigorous biological indicators is a powerful tool for investigating relationships with potential stressors. This approach can be expanded to individual species to delineate environmental preferences, such as sensitivity of brook trout to impervious surfaces that exceed 2% of the watershed (although the confounding effects of geographic correlations between stressors and natural variation need to be considered). Association analysis can also be used to help segregate synergistic or antagonistic effects among stressors. For example, stream nutrient concentrations (as measured by nitrate-nitrogen) concentrations remain relatively stable in watersheds of up to 50% agricultural land, but then concentrations increase substantially with higher proportions of agricultural land.

Ultimately, solutions to stream problems depend on effective restoration at the source of degradation. Within DNR, the Integrated Natural Resource Assessment is collecting stressor information at a watershed scale. Information on the relative importance of stressors is also used by EPA's Mid-Atlantic Integrated Assessment. As the environmental regulatory agency, MDE can use MBSS stressor information to identify industry sectors and land management practices that need further controls. As mentioned above, preliminary stressor information associated with specific degraded stream segments can be used to target additional monitoring leading to listing as 303d streams and subsequent development of TMDLs. This 1995-1997 MBSS report includes a table of 539 degraded stream sites with the associated values for 32 potential stressors. Nutrient contributions from streams can be used by the Tributary Strategy Teams as they develop nutrient reduction plans to meet Chesapeake Bay restoration goals. MBSS nutrient information, as well as data on fish abnormalities, can also help better understand the role of streams on outbreaks of *Pfiesteria* and other toxic organisms.

### 13.2.5 Targeting Restoration Efforts within Maryland

Selecting, designing, and implementing watershed restoration efforts will, in large part, determine the success of DNR's management of Maryland's stream resources. Many questions of public policy will be involved and are outside the realm of environmental assessment and scientific inquiry. In particular, the many uses desired by the public and the values they place on individual resources will affect the management and policy decisions made by DNR and other regulatory and management agencies. Each restoration effort will begin with a goal that defines the desired condition the project is trying to obtain. Whether conditions comparable to those prior to European settlement are appropriate for some or many parts of the state remains to be determined. Just what alternative conditions may be acceptable in developed areas and what ecological functioning can be sustained are also unknown. Regardless of the answers to these questions, science has an increasing role to play in supplying the public with information; now that individual citizens and organized interest groups are engaged in efforts to manage natural resources it is critical that they not be swayed by anecdotes that are not supported by evidence. Scientific information must be at hand when opportunities for major management and policy decisions arise.

The Survey was designed to produce accurate estimates of the extent of stream features, degraded streams, and potential stressors at the statewide and river basin scales. While the 1995-1997 sampling has accomplished this, natural resource managers ultimately need monitoring results on a finer scale. In particular, each of Maryland's 22 counties has boundaries different from the 17 river basins and generally needs a higher density of sample sites. DNR has committed in its Integrated Natural Resource Assessment to characterize watersheds at the 8-digit scale (138 in Maryland) for targeting and planning purposes. The state's 138 watersheds are subunits of the 17 major basins used by MBSS (Figure 13-2; Appendix G). When detailed restoration and management plans are developed, information at the 12-digit watershed scale (1166 in Maryland) may be needed. Beyond this, local scale implementation may require assigning values to entire stream reaches, through an adaptive sampling approach or supplemental field reconnaissance. To demonstrate the utility of existing MBSS data at these finer scales, two sets of estimates are provided as a sidebar to this section—(1) estimates for all Maryland counties and (2) estimates for six small watersheds covering a range of sample density (5 to 36 sites in each).

As described above, data from the 1995-1997 MBSS were incorporated into the Integrated Natural Resource Assessment by DNR's Watershed Management and Analysis Division and used to produce the Unified Watershed Assessment submitted to EPA under the Clean

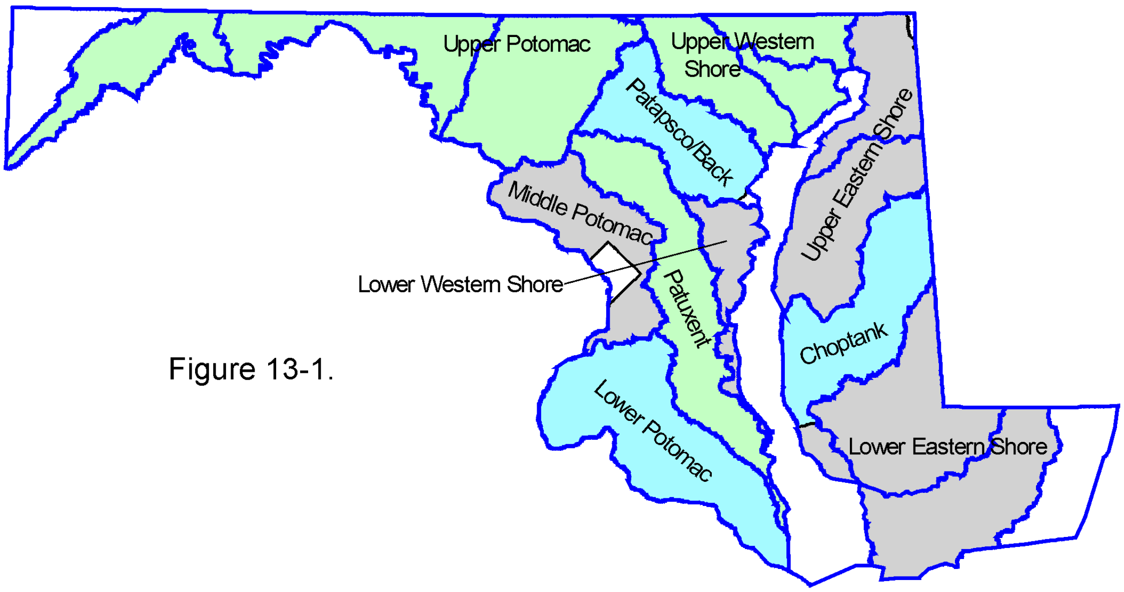


Figure 13-1.

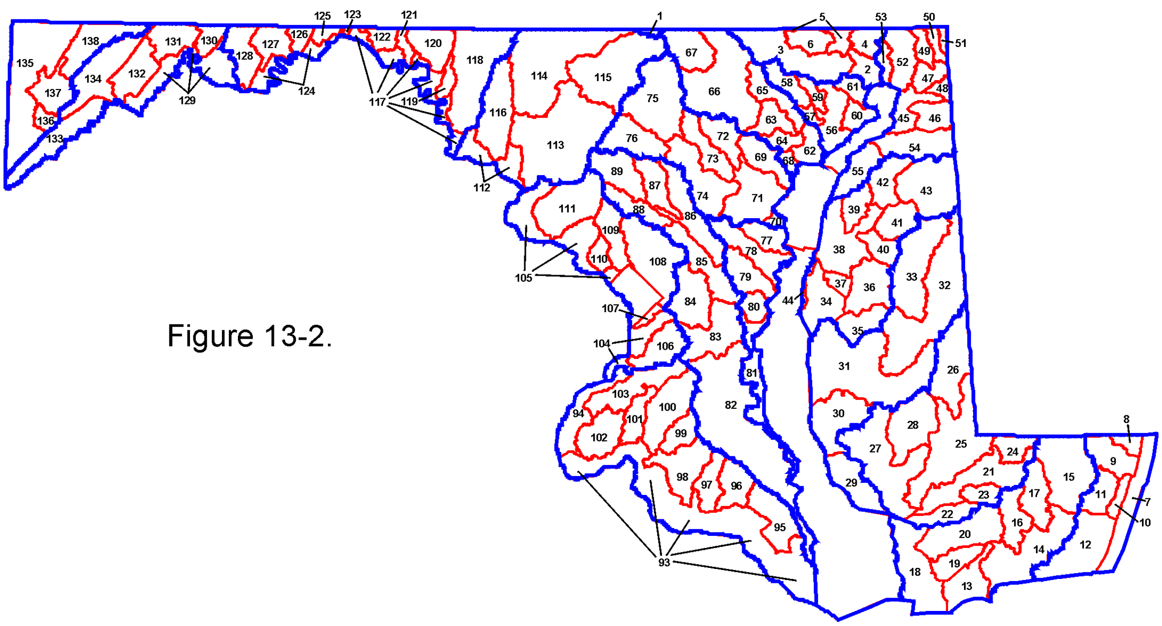

Figure 13-2.

Figure 13-1. Maryland's 10 Tributary Strategies basins. The blue lines show the boundaries of the major river basis used in MBSS reporting.

Figure 13-2. Maryland's 138 8-digit watersheds (in red) within the major river basins used in MBSS reporting (blue)

Water Action Plan. This process has assigned watershed scores to each of the 138 watersheds (excluding those in the Chesapeake Bay) designating its priority for restoration (Category 1). Those watersheds receiving the highest scores for both restoration (Category 1) and protection (Category 3) were selected as highest priority—a total of 11 watersheds. These will be a focus of 1999 restoration efforts by DNR's Watershed Restoration Division under the Clean Water Action Plan and other initiatives.

As an example of further targeting efforts, the Governor has committed to restoring 600 miles of riparian vegetation in Maryland (to meet the "2010 miles of riparian buffer by 2010" Chesapeake Bay watershed goal). Figure 13-3 illustrates the percentage of stream miles in each Maryland river basin that has 19 m of riparian buffer vegetation. This demonstrates that the need for restoring riparian vegetation is greatest in certain basins, e.g., the Patapsco and Middle Potomac. At the same, managers recognize that a watershed approach that addresses total land use composition in addition to riparian reforestation is needed for effective restoration (Center for Watershed Protection 1998). A critical consideration for managers targeting riparian plantings or other stream restoration efforts is the composition and distribution of land ownership across the state.

Information collected by the Survey while contacting landowners for permission to access sampling sites was used to estimate the extent of public (parks, federal facilities, and other state, county, and local government land), private (owned by individuals or businesses), and mixed (both public and private) ownership of land adjacent to stream sites. Individual site data were used to estimate the areawide extent of each type of ownership. A large majority of streamside land is in private ownership (Figures 13-4 and 13-5). Statewide, an estimated 79% of stream miles are on private land, while only 17% are public. Within some individual basins, the extent of private ownership is even higher, with private land encompassing greater than 90% of stream miles in the Choptank and Pocomoke basins. Even among the public lands in Maryland, many areas currently do not provide substantial protection for natural resources. Figure 13-6 illustrates the smaller subset of protected lands, that themselves include open space dedicated to multiple uses. Public lands that are not currently managed for natural values may offer the best opportunities for new restoration efforts. In any case, the predominance of private land ownership in Maryland indicates that natural resource managers will have to work effectively with local land use planners, and private property owners to effect substantial stream and watershed restoration.

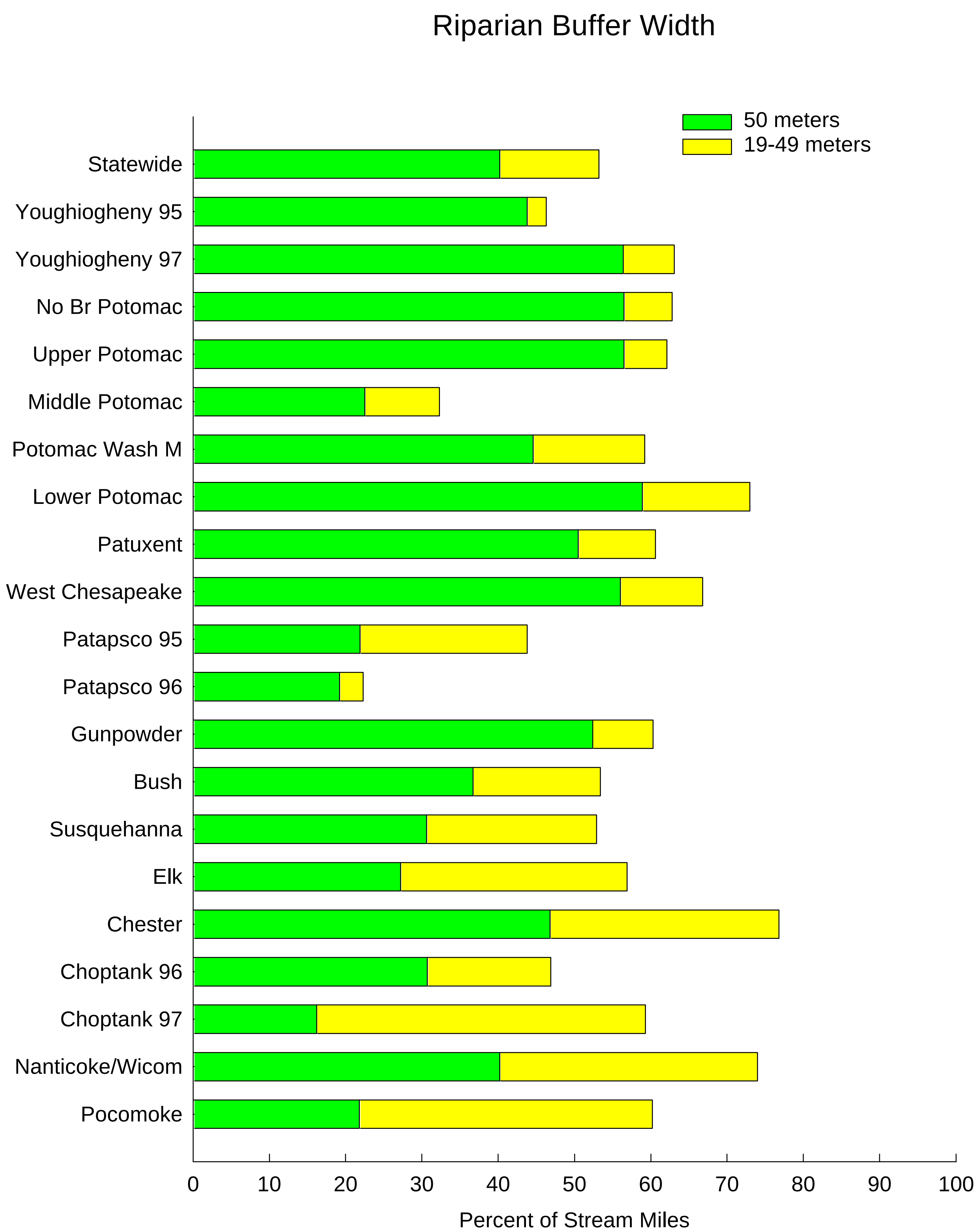


Figure 13-3. Percentage of stream miles with riparian buffer width 19-50 m, statewide and for the basins sampled in the 1995-1997 MBSS

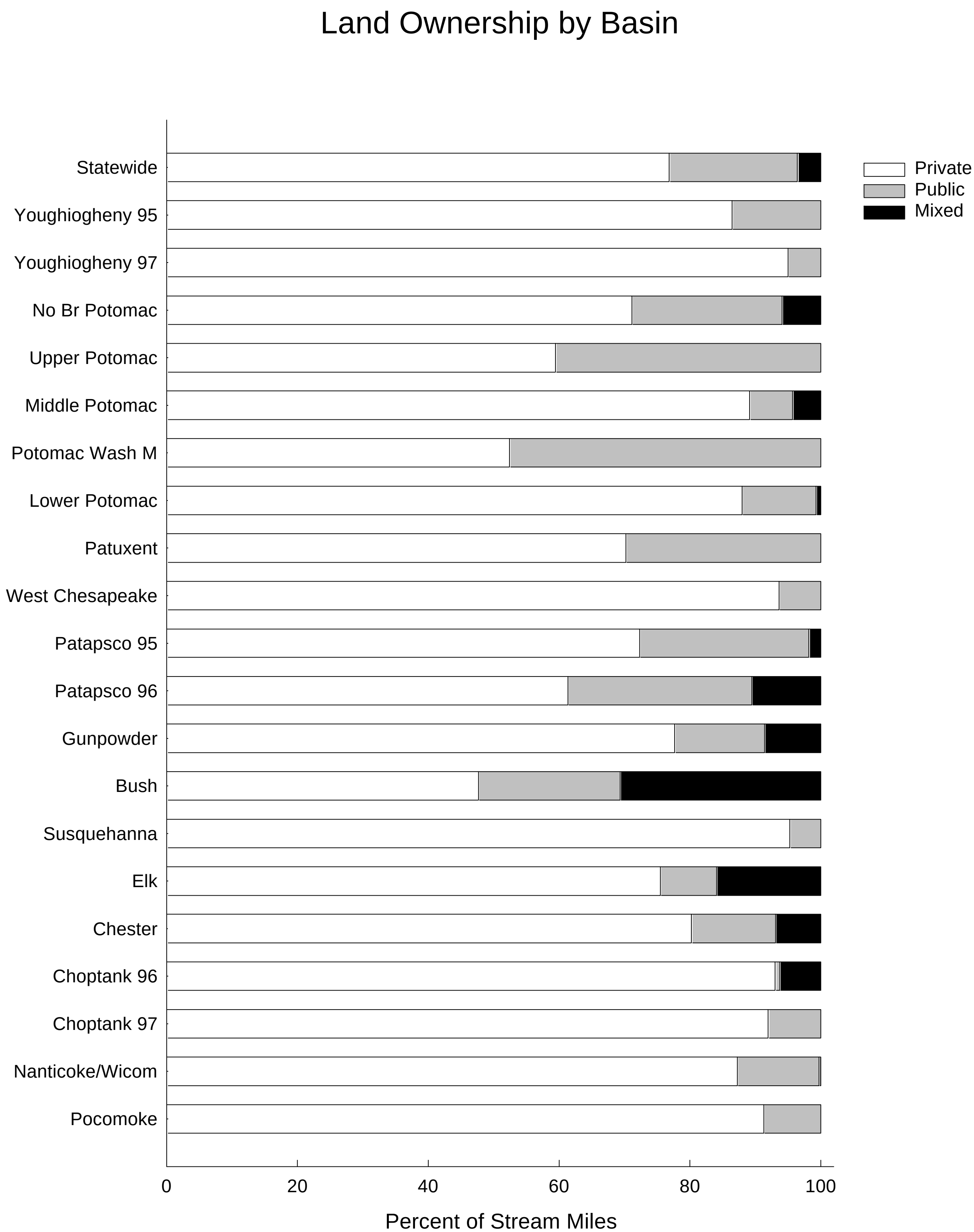


Figure 13-4. Percentage of stream miles that are located on public, private, or mixed ownership land, statewide and for the basins sampled in the 1995-1997 MBSS

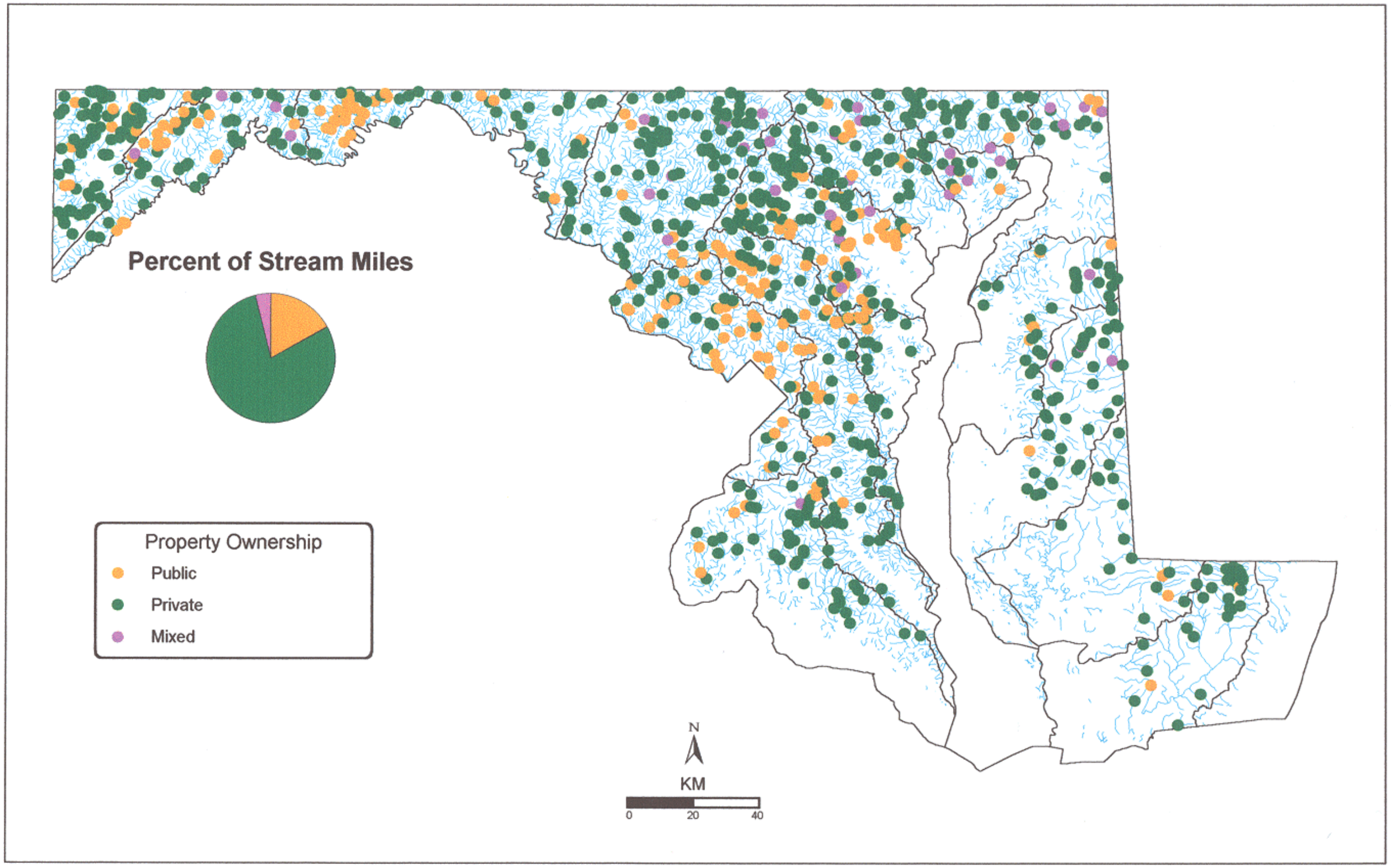


Figure 13-5. Geographic distribution of 1995-1997 MBSS sites that are located on private, public, or mixed ownership land. The pie chart indicates the statewide percent of stream miles in each ownership category.

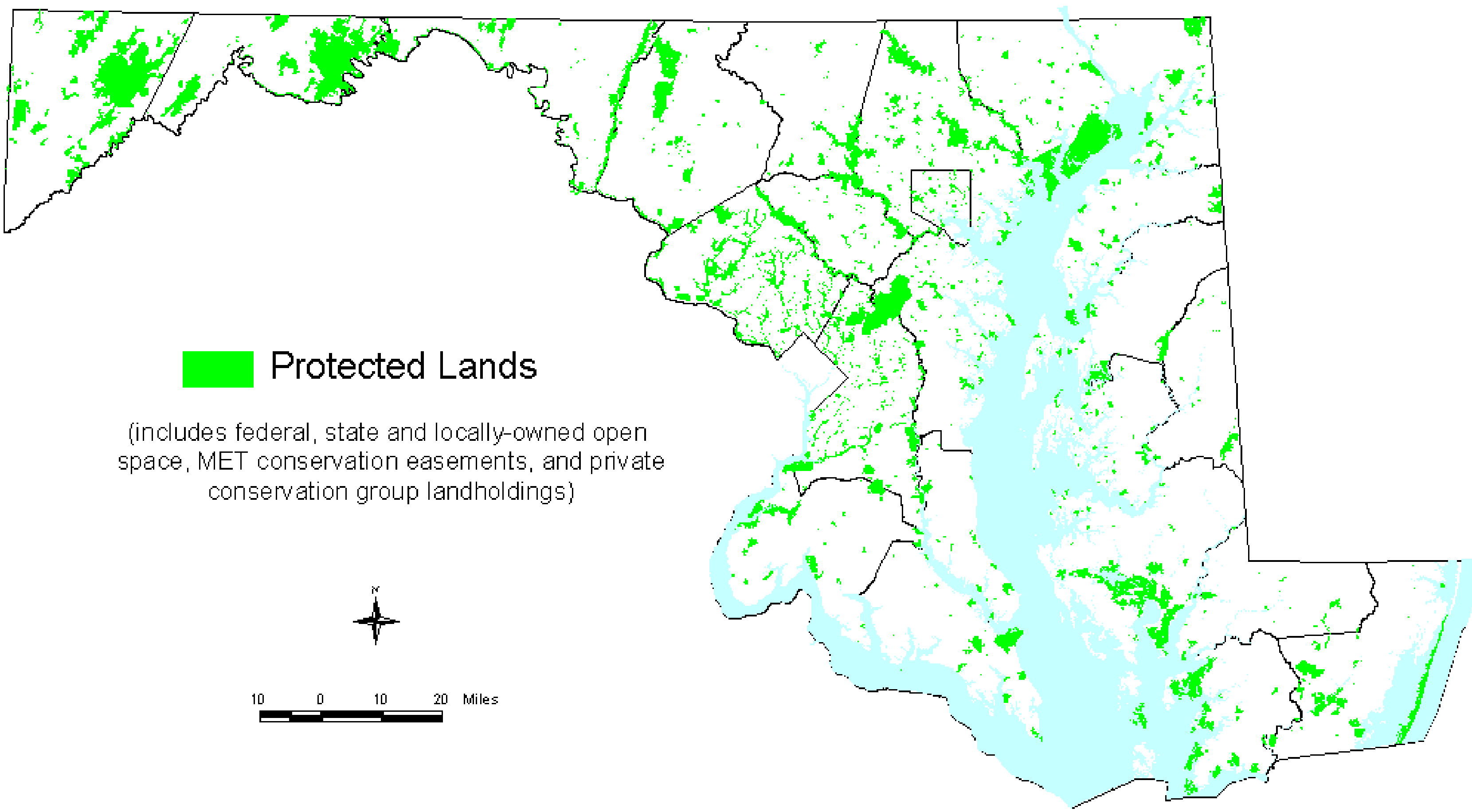


Figure 13-6. Geographic distribution of protected lands

## MBSS County and Watershed Estimates

While the 1995-1997 MBSS was designed to make estimates of stream condition statewide and within the 17 major drainage basins in the state, natural resource managers and policymakers may desire MBSS information on a smaller scale, such as the county or Maryland 8-digit watershed level. Towards this purpose, estimates of the fish and benthic IBIs, as well as the Physical Habitat Index were made for the 24 counties in Maryland (including Baltimore City) and for six selected watersheds throughout the state (Appendix H). A discussion of both countywide and watershed-scale information will be included in future reports.

The fish and benthic IBI scores in five selected counties – Anne Arundel, Baltimore City, Garrett, Montgomery, and Wicomico – are presented in Figure 1. In highly urbanized Baltimore City, the vast majority of stream miles were rated very poor by both the fish and benthic IBI (77% and 97%, respectively). In contrast, Garrett County, a rural county located in western Maryland, the greatest percentage of stream miles was rated good by both the fish and benthic IBI (26% and 28%, respectively). It is important to note that (approximately 25%) of stream miles in Anne Arundel, Garrett, and Montgomery Counties were not assigned a fish IBI score because of small watershed size, supporting the need for a separate indicator for small streams.

The fish and benthic IBIs in four of the six watersheds (selected to provide a range of sample site densities) are presented in Figure 2. Streams in the Deep Creek Lake watershed, located in western Maryland, were in the worst condition according to the fish IBI (63% of stream miles were rated very poor and the remaining 37% were not rated). Gwynns Falls, a watershed located in the Baltimore-Washington corridor, was in the worst condition according to the benthic IBI (57% of stream miles rated very poor). Mattawoman Creek was in the best condition according to both the fish and benthic IBIs (44% and 18%, respectively).

It is important to note that many countywide and watershed-scale estimates of the fish and benthic IBIs and the Physical Habitat Index, had standard errors greater than 100%. This results from the small number of sample sites in many counties or watersheds (see Table H-4). For example, given the six sites were sampled in the summer in Worcester County, forty-six percent of stream miles were rated good using the fish IBI, but the standard error of that estimate was 107. If more precise estimates at these or other fine scales are desired, future MBSS sampling may have to target higher sample densities. It is also important to note that the absence of the smallest streams from the 1995-1997 MBSS sample frame may bias the estimates of condition in watersheds with many small streams such as Deep Creek. The second round of the Survey plans to use a more detailed sample frame to capture more small streams.

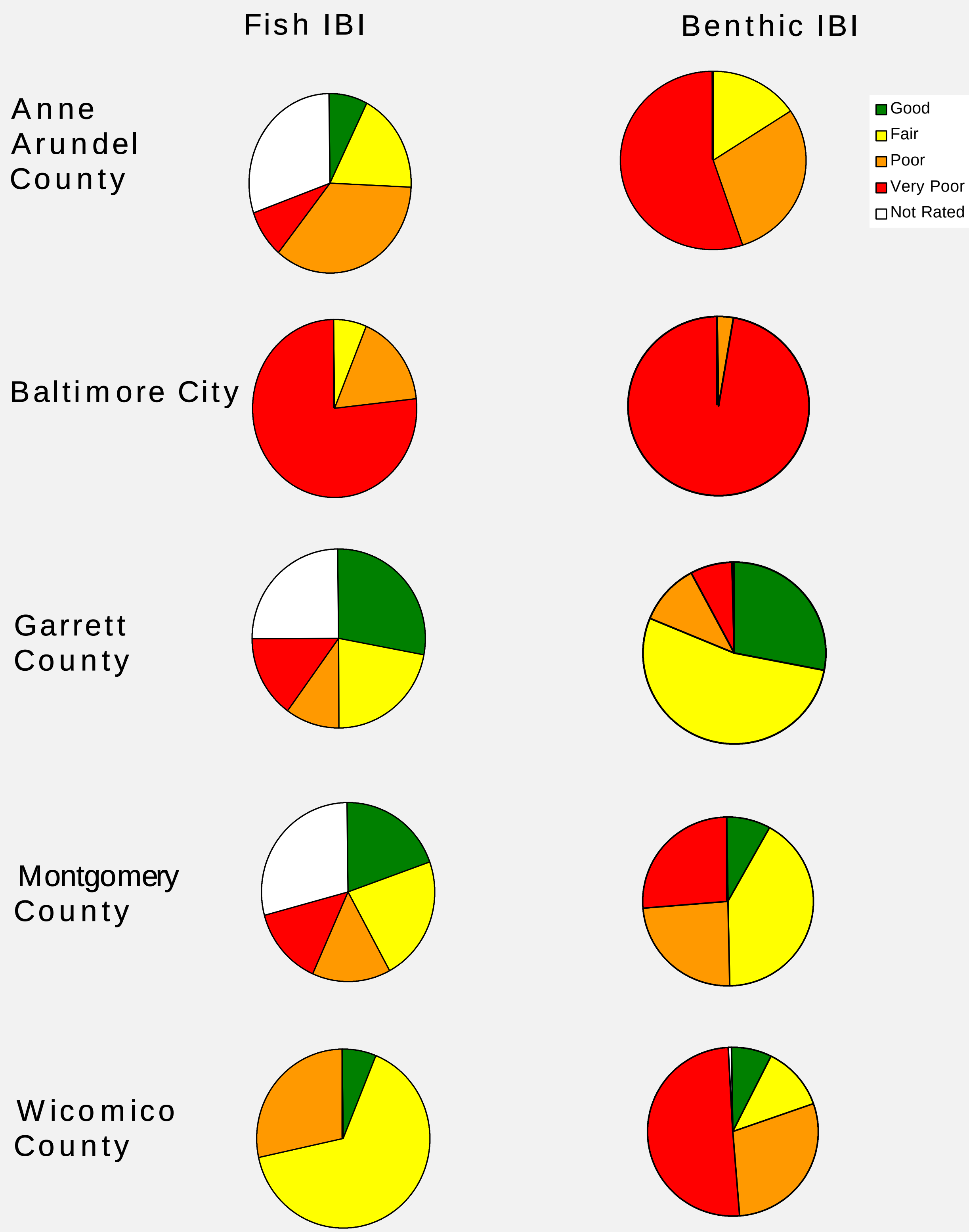


Figure 1. Percentage of stream miles rated good, fair, poor, and very poor by the fish and benthic Indices of Biotic Integrity (IBIs) for five selected Maryland counties

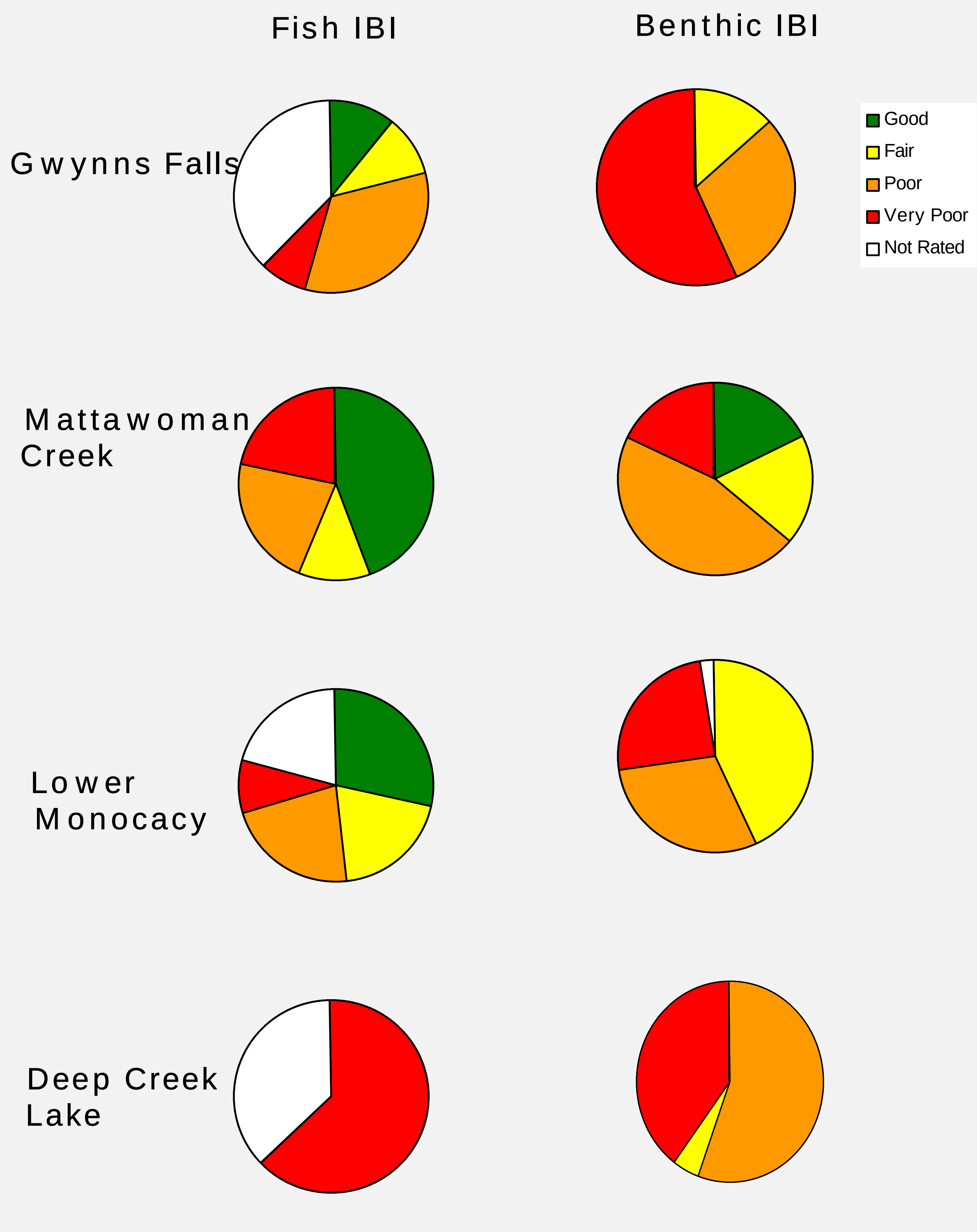


Figure 2. Percentage of stream miles rated good, fair, poor, and very poor by the fish and benthic Indices of Biotic Integrity (IBIs) for four selected Maryland watersheds (Maryland 8-digit code)